NEMATODE SAMPLING: THE LIMITING FACTOR TO VARIABLE RATE APPLICATION

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Abstract

Variable rate application of nematicides requires knowledge of the spatial distribution of nematode population density within a field. The cost of intensive sampling for nematodes can reduce or negate entirely profitability gained from variable rate nematicide application. A 3-year study to determine the changes in nematode population density over time was done in three fields. Population densities of root-knot nematode were grouped into classes of < 250, 250 to 999, 1,000 to 2,499, and ≥ 2,500/500 cm^3 soil. Depending on the field, the area of the field that changed by at least 2 classes after 1 and 2 years ranged from 0 to 29%, and 25 to 54%. If fields could be divided into zones based on different soil properties or yield potentials, then sampling for nematodes by zones may be less expensive than random sampling an entire field. Broad band, multispectral remote sensing was used to group five fields into zones and each zone was sampled multiple times for root-knot nematodes for two years. In all 10 site-year combinations, the minimum number of samples necessary to estimate root-knot nematode density within 25% of the population mean was greater when sampling by reflectance-based classes than sampling based on the entire site as one unit. There were no single bands, or band combinations (including NDVI) of reflected light that consistently predicted root-knot nematode density. Determination of where the nematodes are causing economic crop damage is still the number one limiting factor to success of variable rate application of nematicides.

Introduction

Precision agriculture encompasses a number of activities where the ultimate goal is to improve farming efficiency. Variable rate application of inputs is an important tool within precision agriculture. Nematicides used for nematode control include fumigants like Telone II, which can cost > $40/acre for product, and Temik 15G, where costs can range from $10 - $40/acre, depending on rate (3 to 12 lbs/acre) applied. Recommendations for nematode control have historically been based on the population density of specific nematodes. Nematode population density is typically obtained in the fall of the year, from multiple, composite soil samples. Each sample is the combined mixed soil from 15 to 20 samples taken over an acre or so, in the field. The soil depth typically is from about 4 to 12-inches deep. In west Texas, I typically recommend a producer take at least three composite samples in a 120-acre field. If there are obvious terrain differences or areas with soil texture changes, then a separate composite sample should be taken in these different areas.

The goal of whole field sampling is to obtain a reasonably accurate average nematode population density of what the true mean for that nematode is in a field. Then that value is used to classify the field as treat or no treat (i.e. for fumigation), or treat at a certain rate (i.e. for Temik 15G). In west Texas, for example, if root-knot nematode density is < 250/500 cm^3 soil, I recommend no treatment. If the density is 250 to 999/500 cm^3 soil, I recommend using 3.5 lbs of Temik 15G/acre. For increasing nematode levels above 1,000/500 cm^3 soil, I recommend using higher rates of Temik 15G, fumigation, or crop rotation to a nonhost like peanut. There are many other factors that affect the ability of nematodes to cause crop damage besides density including soil texture (Koenning et al., 1996), water (Kirkpatrick et al., 1995), and weeds (Wheeler et al., 1999). However, if all other factors are the same in the field, then higher nematode densities lead to higher crop losses (Seinhorst, 1965).

Nematodes are aggregated in fields (Goodell and Ferris, 1980; Noe and Campbell, 1985). Using a single rate of nematicide across an entire field means that some areas of the field are receiving product where the nematode is absent. In a case where a single rate of Temik 15G is used, there may also be areas of the field where a better yield response would occur if the rate was increased, but also areas of the field that do not show any additional yield increase over the base rate of 3.5 lbs/acre. Variable rate application of nematicides requires information about the nematode population distribution across the field. Ultimately, it also requires an understanding of the ability of that population to damage cotton in each identified zone of the field. A zone is an identified area where the nematode population densities will cause a similar loss in yield, and where the same rate of nematicide should reduce or eliminate that loss across the zone. Nematode sampling can be very expensive. It takes money to correctly sample a field, store the sample in a suitable environment, and send the sample to be assayed. The cost of the assay alone can range from $10 to $30 per sample. Samples should be processed promptly (within 1-2 wks of sampling, even when refrigerated) to ensure that the nematode counts do not decrease substantially. If a producer goes to the expense of intensively sampling a field with the goal of variable rate nematicide application (which also then requires position information on each sample), then how many years can they wait before needing to sample again? Should a producer divide the field into a series of equally spaced areas, and sample each area, or is there a method where sampling can be more efficient? Since root-knot nematode population density is sensitive to soil texture (Koenning et al., 1996), it would be simple to create zones on soil texture. However, in fields where there are no obvious dramatic soil differences, the question of how to differentiate nematode treatment zones remains. Remote sensing may provide the answer.

Remote sensing can be done close to the plant (usually with a hand held device over the plant), from an airplane where the image is a bit fuzzier than the near-plant image (resolution may range from 1 ft. to 9 ft for an individual pixel), to satellite images, where the resolution for commercially obtained images may range from 3 ft. to 30 ft. The device taking the image has a range of wavelengths that it will cover. For example a camera with normal color film will cover from about 400 to 700 nm, and the picture can be resolved into 3 bands, each around 100 nm in width (400 to 500 nm is the blue band, 500 to 600 nm is the green band, and 600 to 700 nm is the red band). Color infrared film also covers the near infrared spectrum (750 to 900 nm). The near infrared spectrum is of particular value with plants, since leaves reflect light strongly over those wavelengths. Reflectance from the red band is most valuable in looking at soil properties, since the soil tends to reflect light more strongly than the plant at 600 to 700 nm. The green band is a combination of how the soil is reflecting light and also the leaves. Chlorophyll reflects light strongly at 550 nm, though over a broad band, this is somewhat diluted. Narrow bands would involve reflectance over a much smaller range than 100 nm. Multispectral means that the device can obtain reflectance for at least two bands. Hyperspectral means that the device can obtain reflectance information over many, many bands.

Materials and Methods

Sampling over time and space. A study was done during 1996 to 1998 in three fields to determine the variability in time and space of root-knot nematode fall population density in cotton fields. This work has been published (Wheeler et al., 2000). To briefly summarize the study, soil samples were taken in the fall of each year, consisting of 20 cores taken near the taproot of the plant, using a narrow bladed shovel. At each site, 48 composite samples were taken, each in a defined grid, where there were 24 grids, and two samples taken per grid. All samples were assayed for second-stage juveniles (J2) of root-knot nematode using the pie-pan method (Thistlethwayte, 1970) and for eggs using the NaOCl extraction method (Hussey and Barker, 1973). The fall population density (Pf) was defined as the sum of J2 and eggs for each grid location, averaged over the two samples in that grid. The Pf was classified as not damaging (< 250/500 cm^3 soil), low damage potential (250 to 999/500 cm^3 soil), moderately damaging potential (1,000 to 2,499/500 cm^3 soil), and highly damaging potential (> 2,500/500 cm^3 soil). A change of two classes (i.e. from not damaging to moderately damaging potential for example) was considered sufficient to cause a substantial change in management recommendations.

Remote sensing to determine nematode population density. A study was done during 1999 and 2000 at five root-knot nematode infested fields to determine if broadband, multispectral aerial imagery taken during the growing season could be related to fall population density of root-knot nematode in cotton fields. This work has been published (Wheeler and Kaufman, 2003), but the methods will be briefly summarized. Aerial color infrared photographs were taken at an altitude of 2000 ft. above ground level for 60-acre areas, and 4,000 ft. above ground level for fields with 120-acre areas. Pixel resolution was approximately 1 and 2 ft. respectively. The images were obtained on 22, July 1999 and 4, August 2000. The fields selected for the study represented a broad range of soil types and differing densities of root-knot nematode. The images were scanned as JPEG files, and georectified using ArcView GIS 3.2 image analysis program. Each band (green, red, and near-infrared (NIR)) was projected separately as well as the combination of any two bands, using the NDVI index (Schowengerdt, 1997) and all three bands. The variability of reflectance for each of these projections was divided into at least three and not more than six zones. At least five samples were taken from each zone for each band or band combination scenario. Zones from these various band or band combinations represent things like different soil type and plant biomass. These attributes may in turn represent differences caused by nematodes. Since we do not know a specific wavelength or combination of wavelengths that are diagnostic for root-knot nematode damage, we looked at all possible combinations. For each identified zone, five coordinates were selected to sample for nematodes in the fall. Nematode samples were assayed as described previously. Regression analysis were used to relate nematode density and transformed nematode density ($\log_{10}$(root-knot nematode + 1))/500 cm^3 soil, with reflectance values of individual bands and band combinations. In each test, the t-test was significant at P=0.05 for a band or band combination to be acceptable. To address whether it would be more expensive to sample based on zones for variable rate application, cost of Telone II was estimated at $50/acre for a 3 gallon rate and Temik 15G was estimated to cost $3.30/lb of product and soil assay costs were estimated at $25/sample.

Results

Sampling over time and space. The three sites represented a range of responses from almost none to a fairly large change in nematode population density over time. Significant changes in population density one year after sampling (i.e. from 1996 to 1997 or 1997 to 1998) occurred in an average of 13% of the areas in field 1, an average of 21% in field 2 and an average of 19% in field 3. Two years after the initial sampling, significant changes in root-knot nematode population density occurred in 25% of the areas in field 1, 42% of the areas in field 2 and 54% of the areas in field 3. Yearly soil sampling may be necessary to make accurate recommendations for variable rate application of nematicides, if rates are based on nematode density.

Remote sensing to determine nematode population density. Across the 10 site/year combinations, the red band alone, which presumably was a measure of soil differences, was related to root-knot nematode density in four fields. The NIR band, which is a measure of biomass, was related to root-knot nematode density in four fields, and NDVI was related to root-knot nematode density in three fields. A full presentation of all possible combinations can be found in Wheeler and Kaufman, 2003. So, the best of the combinations (NIR alone, Red alone, Green/Red) could be related to nematode density less than half of the time. Even worse, the relationship could be positively correlated between reflectance intensity in one year and negatively correlated the next, or positively correlated in one field and negatively in another. Without an easy indicator like distinct soil texture changes, remote sensing using broad band, multispectral imagery was not successful at indicating nematode zones for sampling. Within a zone, nematode population density could vary tremendously, since zones were a function of other attributes. Reflectance-based zones did not provide for a reduction in nematode population variance, compared with that of the whole field variance. When considering the cost of reflectance based soil sampling, to that of whole field sampling with one rate applied across the field, in most cases, the sampling for variable rate application was greater than the cost of applying the nematicide to the entire field. Until the sampling issues, or other indication of where to apply how much nematicide rate is resolved, variable rate nematicide application will not be consistently profitable.

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